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THE UNIVERSITY OF TEXAS AT AUSTIN

The University of Texas at Austin

McDonald Observatory

and

Department of Astronomy

NASA Grant NGR 44-012-152

SEMIANNUAL REPORT #21

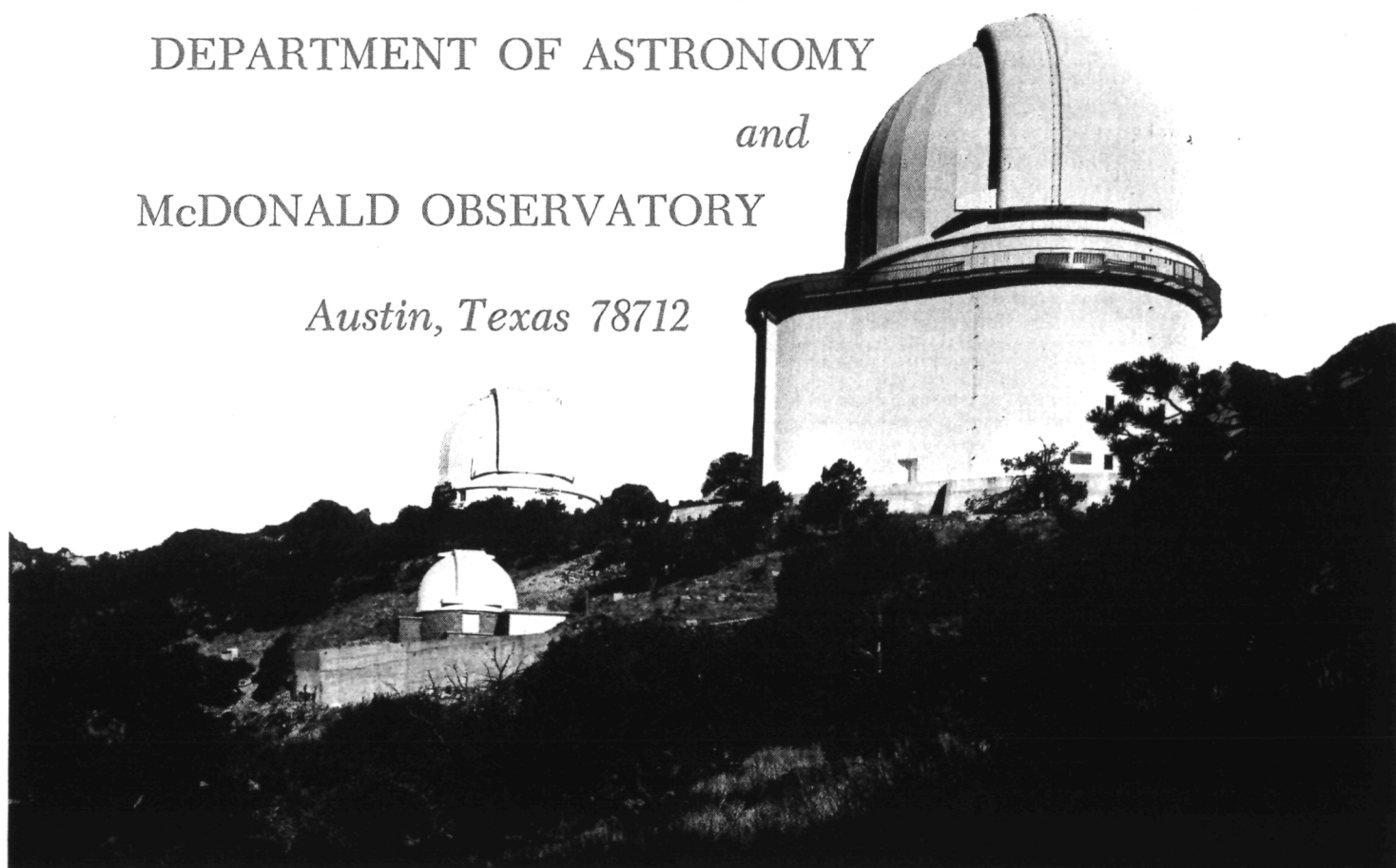
Period: January 1, 1984 to June 30, 1984

DEPARTMENT OF ASTRONOMY

and

McDONALD OBSERVATORY

Austin, Texas 78712



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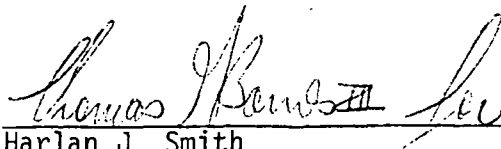
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Period: January 1, 1984 to June 30, 1984

Submitted:


Harlan J. Smith

1. Personnel working on this Grant during the reporting period

Dr. Harlan Smith (Principal Investigator, not charged to grant)
Dr. Laurence Trafton (Co-Investigator, full time)
Dr. Edwin Barker (Co-Investigator, 1 month charged to grant)
Dr. William Cochran (Co-Investigator, 1 month charged to grant)
Dr. Robert Tull (Senior Research Scientist, not charged to grant)
Dr. Anita Cochran (Postdoctoral Associate, 1 month charged to grant)
Dr. Brenda Young (Research Scientist Assoc. III, not charged to grant)
Mark Sutherland (Lab Research Asst. II, half-time until Feb 29)
Kam Sun (Lab Research Asst. II, half-time starting Feb 1)
Greg Osterman (Lab Research Asst. I, variable hrs., not charged to grant)
Alice Herzog (Sr. Secretary, 20% time)
Denise Lipford (Sr. Administrative Clerk, 25% time)

Other activities of associated personnel:

L. Trafton spent the periods 25-31 January and 1-7 April working on his Space Telescope contract with NASA Goddard.

Denise Lipford and Mark Sutherland left during this reporting period.
Kam Sun has started working half-time as a Lab Research Assistant II.

As a member of the Texas 7.6-m telescope site selection committee,
E. Barker has been heavily involved with the site survey for this project.

II. Overview and Summary

A bimodal haze forms in Saturn's atmosphere is lagged seasonal response to reduced insolation such as occurs from Saturn's obliquity, elliptical orbit and Ring shadow passage. The upper level is near the tropopause and probably consists of NH_3 particles (rather than CH_4) carried upward by convective overshoot and eddy diffusion. Significant seasonal changes extend to the deepest visible parts of the atmosphere as a result of dynamical processes and the thermodynamics of phase changes.

An anomalous ortho-para H_2 ratio appeared in 1978 which may have signaled a rapid rise of the radiative - convective boundary from deep levels following maximum tropospheric temperature (when the radiative stability would have been a maximum).

IDS spectra and CCD photometry were obtained of P/Crommelin during the IHW (International Halley Watch) trial run March, 25-31, 1984.

The molecule CH in comets is being studied to determine what role CH_4 plays in comets. CH may be a very important tracer of parent activity in a cometary coma.

The Washington University CCD system has been used successfully at the scanner focus of the 2.7m coude spectrograph. This detector allows very high spectral resolution (0.020 \AA) to be coupled with the two-dimensional multiplexing capabilities of the CCD.

III. Observational Research Program

A. NASA-Texas Observing Runs

Dates (Civil)	Possible Hours ¹	Unobservable Hours ²	Observed Hours ³	Telescope	Focus
23 Jan - 25 Jan	33	16	17	2.1m	Cassegrain
20 Feb - 23 Feb	40	5	35	2.1m	Cassegrain
24 Feb - 26 Feb	30	16	14	2.7m	Cassegrain
12 Mar - 21 Mar	100	9	91	2.7m	Coude
19 Mar - 21 Mar	27	0	27	2.1m	Cassegrain
26 Mar - 1 Apr	69	20.5	48.5	2.7m	Cassegrain
16 Apr - 19 Apr	32	12	20	2.7m	Coude
23 Apr - 29 Apr	56	18	38	2.1m	Cassegrain
14 May - 23 May	85	41.5	43.5	2.7m	Coude
31 May - 3 Jun	28	21	7	2.7m	Cassegrain
31 May - 3 Jun	28	23	5	2.1m	Cassegrain
7 Jun - 20 Jun	116	95	21	2.7m	Coude

¹Possible Hours =Hours during which objects of interest were available minus laser runs minus time shared with nonplanetary observers.

²Unobservable Hours =Hours during which observations were not made due to inclement weather or equipment failure.

³Observable Hours =Hours of actual observation or calibration.

B. Other Planetary Observing Runs

Dates (Civil)	Observer	Institution	Telescope	Focus
20 Jan - 26 Jan	A. Potter	NASA/JSC	2.7m	Coude
30 Jan - 5 Feb	R. Binzel	U.T. Austin	0.9m	Cassegrain
2 Mar - 7 Mar	R. Binzel	U.T. Austin	0.9m	Cassegrain
26 Mar - 28 Mar	D. Mulholland	U.T. Austin	2.1m	Cassegrain
26 Mar - 1 Apr	D. Mulholland	U.T. Austin	0.8m	Cassegrain
23 Apr - 29 Apr	D. Mulholland	U.T. Austin	0.9m	Cassegrain
30 Apr - 6 Apr	R. Binzel	U.T. Austin	0.9m	Cassegrain
14 May - 20 May	J. Bergstralh	NASA/JPL	2.1m	Cassegrain
18 May - 24 May	A. Potter	NASA/JSC	2.7m	Coude-daytime
25 Jun - 27 Jun	D. Mulholland	U.T. Austin	2.1m	Cassegrain

C. Observations made during this reporting period

Very poor weather in May and June seriously hampered efforts to obtain several important observations. These observations must be postponed; some to later this year, and others to next year.

Mercury, Venus, Mars

No observations were made during this reporting period.

Jupiter

One scanner observation of the H_2 $S_3(0)$ quadrupole line was squeezed in as part of a program for long term seasonal monitoring. The quadrupole lines, formed by the dominant gas of the atmosphere, have proven to be excellent probes of the aerosol content and ortho/para ratio of the outer planet atmospheres. More observations are planned in the next observing period when this line will be available at a Doppler shift clear of telluric H_2O lines.

Long-slit coude CCD spectra (see Section IV-Instrumentation) were taken of the equatorial region of Jupiter centered at 6367 \AA (H_2 4-0 $S(1)$ line), and 6135 \AA (H_2 4-0 $S(0)$ line, and several NH_3 lines). These spectra were obtained to test the technique of exploiting the two dimensional format of the CCD to obtain in a single exposure the center-to-limb variation (CTLV) of a planetary absorption line. The method looks very promising from a preliminary look at the spectra at the telescope. We gain a factor of about 20 in speed over our previous technique in CTLV studies of taking single Reticon spectra of isolated spots on the disk.

Saturn

As part of our long term seasonal monitoring effort (see Section VI), we obtained one observation each of the $S_3(0)$ and $S_3(1)$ H_2 quadrupole lines and five observations of the $Q_3(1)$ line with lunar comparison spectra for removing the strong background Fraunhofer line whose wing blends with the H_2 line. Further observations are planned for the next half year.

Fifteen observations of Saturn's NH_3 6450 Å band were obtained at various locations along the central meridian in order to assess the effect of changing season on the main cloud deck (see Section VI).

For the same purpose, ten observations of the solar Ca II H and K lines were obtained at similar locations on Saturn's disk, along with lunar comparisons.

Eight spectra of CH_4 bands in the 0.68-1.06 μm region were also obtained in order to assess seasonal effects near the Tropopause (see Section VI).

Long-slit coude CCD spectra were taken of the H_2 quadrupole $\text{S}_4(0)$ and $\text{S}_4(1)$ lines. With the CCD, we were able to cover the entire diameter of the planet in a single exposure. For each line, spectra were taken with the slit along the central meridian, along the equator, and in the north temperature region. Each CCD exposure gives us the variation in the equivalent width of the line from the disk center to both limbs.

Uranus

Since the steep obliquity of Uranus' rotation axis (97.9°) should cause strong seasonal effects in the atmosphere, and since the planet is currently nearly pole-on to the sun, when the heating rate is maximum for the illuminated hemisphere, we obtained spectra (one each) of the solar Ca II H, K lines, in order to study seasonal changes in the aerosol distribution.

We obtained one spectrum of the CH_4 $3\nu_3$ band $\text{R}(0)$ line, and a Saturn comparison spectrum, but the signal is too low to be of use without further observation. This line is a singlet, and its width provides information on the effective pressure of its formation region. This effective pressure is proportional to the total gas content at that level.

Coude CCD spectra were obtained of the H_2 quadrupole $\text{S}_3(0)$ line. The H_2 quadrupole lines are both pressure narrowed and pressure shifted.

Thus, high spectral resolution line profiles are able to provide depth resolution within the atmosphere, giving information on the aerosol distribution and the ortho/para ratio in the atmosphere. The spectra were taken using the echelle grating in double pass, with the CCD at the "scanner focus" of the spectrograph. This combination gives a spectral resolution element of about 0.020 \AA . Since Uranus is nearly pole on this year, the rotational broadening of the line will be a minimum this year.

Poor weather prevented obtaining data on the $\text{H}_2 \text{S}_3(1)$ line in June. This line will be Doppler shifted into a weak telluric H_2O line for the remainder of this season. Therefore observation of the $\text{H}_2 \text{S}_3(1)$ line must be postponed until next year. However, the $\text{H}_2 \text{S}_3(0)$ and $\text{Q}_3(1)$ lines will remain observable during the summer.

Neptune

Four spectra were obtained of the $0.68\text{-}1.06 \text{ \mu m}$ CH_4 bands for the survey of long-term variations in the atmospheres of the outer planets. These spectra suffered from noise pickup by the Varian PMT of stray noise sources within the spectrograph (such as the Reticon cooling System), as discussed in Section IV. The spectra are probably useable in spite of this problem, although their quality is low.

Pluto

We obtained cassegrain CCD spectra of Pluto from $7500\text{-}10500 \text{ \AA}$ on five nights in April. This represents a complementary set of data to our Pluto data from a year ago. We will use these data to search for variability of CH_4 absorption with rotational phase.

Titan

One spectrum of the solar Ca II H and K lines was obtained to check earlier work; more will be needed to get a good S/N ratio. The profiles of these solar lines reflected from the atmosphere are diagnostic of the aerosol and Raman scattering within the atmosphere.

Three spectra of low counts were obtained of the $\text{CH}_4 3\nu_3$ manifold, but these are unusable because of the Varian PMT noise pickup problem

discussed in Section IV. We expect to get much better spectra later this year, when the noise problem is fixed.

Two coude spectra of the $0.68\text{-}1.06\ \mu\text{m}$ CH_4 bands were obtained for studies of temporal variability. Although these spectra suffer from the same noise problem, they are usable.

Iapetus

We were scheduled for an observing run with the 2.1m cassegrain Reticon spectrograph centered on the eastern elongation of Iapetus. Our purpose was to obtain new near-infrared spectra of the dark side of Iapetus, in order to resolve differences between spectra previously obtained by different groups. Unfortunately, poor weather limited us to just a few spectra taken 1-1/2 days from full elongation. The next favorable eastern elongation will be in 1985.

Asteroids

S. Sawyer has continued his CCD spectrophotometric survey of a large sample of asteroids in the $0.75\text{-}1.10\ \mu\text{m}$ region at $\sim 10\ \text{\AA}$ resolution. In spite of poor weather, he has obtained spectrophotometry on 42 asteroids, and spectroscopy on 30 additional asteroids.

As part of our continuing program to observe faint peculiar asteroids, we obtained IDS spectra of seven asteroids. Observations of four asteroids (335 Roberta, 619 Triberga, 817 Annika, and 1379 Lomonosowa) were requested by R. Binzel. These asteroids are in orbits near the 3:1 resonance with Jupiter. Spectra were also obtained of 1975QD (a Trojan), 1984KB (an Apollo with $q=0.53\text{Au}$), and 1984BC (an asteroid in a distinctly "cometary" orbit, which will approach to within $0.7\ \text{Au}$ of Jupiter in early 1986).

Comets

Three 2.7m cassegrain observing runs were scheduled for the faint comet survey program using the IDS (Intensified Dissector Scanner) spectrograph on the 2.7m telescope. The following table summarizes the spectra taken at 11 Å resolution covering the region from 3500 Å to 6600 Å.

Comet	Heliocentric Distance (AU)	Spatial Coverage of Coma	No of Days of Observation
P/Crommelin	0.7 _o , 1.0 _o	yes	7
P/Taylor	2.0 _o , 2.1 _o	no	2
P/Harrington-Abell	2.0 _o	no	1
P/Smirnova-Chernykh	3.5 _p , 3.6 _o	no	2
IRAS (1983o)	2.5 _o , 2.6 _o	no	2
P/Wild 2	2.3 _i , 2.0 _i	no	2
P/Clark	1.8 _i , 1.6 _i	no	3
P/Russell 4	2.3 _o	no	1
P/SW 1	6.2 _i	no	1
P/Hartley-IRAS	2.3 _o	no	1
P/Encke	1.4 _o	no	1
IRAS (1983k)	4.2 _o	no	1

i = pre-perihelion, p = perihelion, o = post-perihelion

During two of our 2.7m runs we were able to obtain spectra of the available comets. Poor weather severely restricted the third run in early June, causing us to lose most of the proposed targets.

We participated in the International Halley Watch (IHW) trial run on P/Crommelin during late March. We obtained spectra for the Spectroscopy and Spectrophotometry Network and CCD images through the IAU comet filters for the Near Nucleus Studies Network. Good spectra were obtained with some spatial resolution within the coma. The CCD imaging was limited to a single pair of images in the C_2 emission band and dust continuum due to a lack of photometric weather and instrumental problems with the CCD system. These data will be transmitted to the IHW discipline specialists when the data reduction is complete.

D. Future Observing Runs

2.7m

12 Jul - 19 Jul
10 Aug - 16 Aug

Coude
Coude

Planetary Spectroscopy
Planetary Spectroscopy

0.9m

23 Jul - 1 Aug

Cassegrain

Asteroid photometry (Binzel)

Requested Observing Runs (September-November 1984)

2.7m

Faint comet survey
P/Halley-CCD photometry

3 nights/month
2 runs @ 3 nights each

2.1m

CCD spectrophotometry of
Trojan asteroids (in collaboration
with P. Johnson - U. of Wyoming)

7 nights in September

0.8m

Io reappearances (CCD) -as available

IV. Instrumentation

Octicon (an NSF Project)

After some 5 years of development in the laboratory, Octicon, a linear array of eight 1872-element Reticon arrays, has been completed; the system was delivered to McDonald Observatory on June 27, 1984, and was installed in the 2.7-m coude spectrograph during the following week. The first astronomical observations were obtained on July 7.

The concept of Octicon was first suggested by observatory director Harlan Smith some years ago. Steven Vogt (now an assistant professor of astronomy at Lick Observatory), while a doctoral candidate at Texas, revived the suggestion and, together with Robert Tull and David Lambert, submitted the successful proposal to NSF; funding was received in January, 1979. Vogt subsequently left Texas for his current position. A post-doctoral position was created for a project scientist to carry out design and completion of the Octicon; however this was an unsuccessful venture and it eventually became necessary to carry out the project using available people within the McDonald Observatory staff, with Tull serving as project scientist.

The vacuum chamber and dewars were designed and built to UT specifications by Frank Melscheimer (DFM Engineering, Boulder, Colo.). Tull carried out the optical, mechanical, and electronic specification and design aspects of the project, with detailed design and fabrication of electronics modules by A. Mitchell and K. Darden and other members of the McDonald Observatory electronics engineering group; computing engineer Steven Blachman designed and assembled the computer control system and carried out all programming; Dr. Brenda Young took on the principal responsibilities of bringing the entire system together, testing all components and the completed system, and supervising installation. Training of observers will be primarily the responsibility of Young and Blachman.

Octicon is a complex instrument involving eight Reticon arrays, each with four video output lines; the necessary 32 preamplifiers and two

16-channel analog multiplexers are of necessity mounted inside the vacuum chamber housing the arrays, in order to avoid the large number of vacuum feedthroughs otherwise needed and to assure adequate shielding of these circuits. This necessitated creating and testing a new low-noise, JFET-input preamp design to replace the too-bulky commercial preamps used with other McDonald Reticon systems.

On completion, assembly and installation were carried out at the focus of the shorter of two photographic Schmidt cameras of the coude spectrograph of the 2.7-m telescope at McDonald Observatory. No major problems were encountered, and full operation of all eight detector arrays was achieved, with all data being displayed on the large screen TV monitor of a Grinnell display system and with fully successful data storage on 9-track mag tape in FITS format. Control of the entire system is by an Intel 8086 microprocessor using standard Intel cards, representing a major step away from the NOVA computers we have used over the past 15 years for control of astronomical observations (however, a NOVA computer is used in the Octicon system for communication between the 8086 system and the 10 Mbyte disk and 9-track tape drives, for control of the grating drive, and for other auxiliary functions).

Octicon is mounted at the 1.83-m focus of a 1 m diameter Schmidt camera. The slit projection factor is approximately 4.4, and the image scale 10 arcsec/mm. The pixels are placed linearly along the focal plane with 15 micron center-to-center spacing; each pixel has an effective light sensitive area 15 by 750 microns. Each individual Reticon array has 1,872 pixels in a linear array of length 28.08 mm and width 750 microns; the arrays (each of which is locally flat) are placed along the curved focal surface of the Schmidt camera in contact with an aluminum rod serving as a cold source. Each Reticon lies under a cylindrical lens which serves the dual functions of (1) magnifying the array's width (thus increasing the effective size of the area projected on the sky; all light passing through approximately 12 mm of slit length is received by the Reticon, reducing array alignment problems) and (2) spreading the light from each point of the image uniformly along the length of all pixels (improving the precision

of flat field corrections and preventing spillover of light onto the photosensitive regions occupied by logic elements, including shift registers, alongside the pixel area proper). Along the focal surface, the individual Reticons are at 46.16 mm centers, leaving a gap of about 18 mm between Reticons. This gap will be increased somewhat when the ends of each Reticon are covered to create a dark reference, standard practice in the McDonald Observatory Reticon systems. The expected normal observing sequence will require two exposures, separated by a grating shift, for complete spectral coverage with the gaps filled. At 4.4 Å/mm with gratings A, B, or D, the effective length of the detector array is 0.38 m; two exposures will cover approximately 1,600 Å of the spectrum and will produce 25,000 data points after correcting for overlap and dark reference diodes (thus removing 4600 data points from the original set of nearly 30,000). The data management problems created, while more severe than with the existing single Reticon and Digicon systems, are not as severe as with CCD systems and are not expected to present serious difficulties beyond increased costs of data storage media and increased expectations for research output. Data records are produced on mag tape in the same format as produced by the existing 2.7-m coude Reticon and initial data reduction will be accomplished with existing computer programs, modified to accept the input parameters peculiar to Octicon.

Regular observing with Octicon will be scheduled during the fall quarter beginning in September 1984. It should be useful for planetary as well as stellar observations, and may prove uniquely well suited to the question of spectroscopic detection of planets around other stars.

2.7m Coude Scanner

Observations using the Varian photomultiplier tube were plagued by a noise pickup of the Reticon cooling system solenoid and other sources of electromagnetic noise in the spectrograph. These intermittent noise sources would cause serious problems with the observation of faint objects.

A problem with the 2.7m coude scanner arose in the lack of agreement between the forward and reverse scans. This problem has been traced to wear on the driving screw, and has been fixed by appropriate adjustment.

2.7m Coude CCD

In collaboration with W. H. Smith and W. V. Schempp of Washington University, we have constructed a mounting plate to place the Washington University CCD camera at the scanner focus of the 2.7m coude spectrograph. This focus gives very high dispersion $\sim 1 \text{ mm}/\text{\AA}$ for 1200 g/mm gratings, and $\sim 8 \text{ mm}/\text{\AA}$ with the echelle grating in double pass in the near infrared. The high quantum efficiency and multiplexing characteristics of the CCD make very high dispersion spectroscopy feasible for fainter objects.

The installation of the CCD was quite simple; we used the kinematic mount plate from the old S-1 photomultiplier tube (no longer in use). After carefully focusing the CCD we measured an instrumental profile of $\sim 0.020 \text{ \AA}$, using the He-Ne laser through "closed" slits. The laser line appeared to be double-peaked. We are unsure whether we were actually resolving mode structure in the laser, or if we have encountered some unknown peculiarity of the spectrograph/detector system.

The results from this system were encouraging. A two hour integration on the $\text{H}_2 \text{ S}_3(0)$ line of Uranus gave a signal-to-noise ratio of ~ 100 . The two dimensional format of the detector allows spatial resolution along the slit. The 9.6 mm height of the array allows about 22 arcsec of the object to be recorded. The entire diameter of Saturn may be observed, while two or three overlapping exposures would be required to obtain spectra of a complete diameter of Jupiter.

A difficulty with the CCD system is the fringe patterns. In this thinned, back illuminated chip, the fringing is quite severe in the red, about 15-20% peak-to-peak amplitude. So far, the fringing appears to be quite stable in time; the ratio of flat-field images taken several hours apart is essentially a constant. However, division of the spectrum of an astronomical object by a flat field frame does not fully remove the fringes. When we use the spectrum of a hot star for calibration, cancellation of the fringes is improved. Thus, the fringing seems to be a function of the intensity distribution.

2.7m Radial Velocity Spectrometer

W. Cochran has received a grant from the NSF to continue development of a prototype ultra-high precision radial velocity spectrometer. The instrument is designed to measure stellar radial velocity variations to a precision of a few meters per second. One of the primary scientific goals of this instrument is to search for planetary systems in orbit around other stars.

The optical design of the prototype has been finalized around an astigmatism compensated Ebert-Fastie system. All of the optical components have been ordered, and most have arrived. The prototype will be assembled and tested during the summer and fall 1984.

V. Data Reduction

We are pleased to report that reduction of raw IDS comet and asteroid data is now fully up to date. Spectra of 44 comets and several asteroids are in final form for analysis. We are continuing to reduce the observed band intensities to column densities for several comets.

The processing of CCD images of P/Crommelin and P/Halley are nearing completion.

Spatially resolved spectra of Saturn's 6450 Å NH_3 band along the central meridian have been reduced and combined with previous observations of this band in a paper submitted for publication (see Section VI).

Reduction of the coude CCD spectra taken with the Washington University CCD system will be difficult and time consuming. The data all show a very pronounced pattern of interference fringes formed within the thinned, back-illuminated CCD chip. The fringe amplitude ranges from 5% to 15%. The pattern appears to be reasonably stable and reproducible. Data reduction will begin as soon as we develop an efficient method of transferring data from the cartridge tape on the data acquisition computer to a data medium readable by the computer in Austin.

VI. Analysis and Theoretical Studies

A paper on the long term variations of Saturn's spectrum has been completed by L. Trafton and submitted for publication in Icarus. It covers the H_2 and CH_4 absorption variations over one half of Saturn's year so significant seasonal changes are manifest. Ammonia observations since 1980 are also included.

Saturn's obliquity, orbital eccentricity and Ring shadow have comparable seasonal effects on Saturn's troposphere. A bimodal haze distribution exists with depth for latitudes outside of the equatorial belt. The upper haze is near the tropopause and appears to be NH_3 rather than CH_4 crystals. It forms in lagged response to reduced insolation. The effect of spring was to promptly lower the visual "cloud deck". Saturn's CH_4/H_2 ratio is probably at least 4.7×10^{-3} . An anomalous ortho-

para H₂ ratio appeared in 1978 which may have signaled a rise in the radiative-convective boundary from deep levels following maximum tropospheric temperature and the associated maximum radiative stability. Significant seasonal changes extend to the deepest visible parts of the atmosphere in spite of the large radiative time constant at those depths compared to the length of a Saturn season. This is further evidence that these depths are governed by processes having much shorter time constants such as dynamics and the thermodynamics of phase changes.

VII. Analysis and Theoretical Studies

A. Cochran has been pursuing study of the molecule CH in comets. Of the many comets which are part of the faint comet survey data set, only a dozen have detectible CH. Cochran has found that plots of log column density versus log radial position can generally be fit by a straight line. This is not typical of photolytic processes. However, the slope of this line is not the same from comet to comet. It is generally inversely proportional to abundance of other volatiles such as CN. The slopes are generally ≥ -1 so this process for CH formation is not directly related to spherical outflow. With the short lifetime against photolysis of CH, this relation is a tracer of the parent of CH. Study of this important topic is continuing.

Chemical modeling of several more comets has begun. The comets being modeled represent comets with the most extreme variations in slope in the CH relation discussed above.

W. Cochran has installed his Raman scattering radiative transfer code on the Astronomy Department VAX computer. In doing so, the code has been made significantly easier to use. At the request of R. West (then of Colorado University, now of JPL), Cochran used the code to make some calculations in preparation for the Voyager Uranus encounter. The Voyager PPS instrument has a 300 Å wide bandpass filter, with an effective wavelength of 2640 Å. West needed to know if Raman scattering is a significant factor in the atmosphere of Uranus at this wavelength. The results of the detailed calculations indicate that Raman scattering is indeed quite important in determining the albedo of Uranus in the 2500-2800 Å interval. Because of several changes in the slope of the solar

spectrum in the ultraviolet, simple approximations in the treatment of Raman scattering (such as the common assumption that all vibrationally scattered photons are lost) are grossly inadequate. Detailed calculations giving full treatment to Raman scattering will be necessary for analysis of the Voyager data. These results have been sent to West.

The determination of the absolute flux distributions and geometric albedos of Uranus, Neptune and Titan from data obtained in May 1981 in collaboration with J. Neff (Iowa) and J. Bergstralh (JPL) is now complete. These results are the only spectrophotometric data on Uranus, Neptune and Titan covering the entire visible spectrum from 3500 Å to 10500 Å at high spectral resolution of (about 7 Å) and high signal-to-noise ratio. Our measurements of the geometric albedo of Uranus are in excellent agreement with the results of Lockwood et al. (Ap.J. , 266, 402, 1983). We feel that the work demonstrated the superb accuracy, precision, and efficiency of the Reticon spectrophotometer.

VIII. Publications and Presentations

A. Published Papers

"Large Seasonal Variations in Triton's Atmosphere" L. Trafton, Icarus, 58, 312, 1984.

"Constraints on Bulk Composition, Seasonal Variation, and Global Dynamics of Pluto's Atmosphere" S. A. Stern and L. Trafton, Icarus, 57, 231, 1984.

"Comparison of Groundbased and Viking Orbital Measurements of Martian Water Vapor: Variability of the Seasonal Cycle" B. Jakosky and E. Barker, Icarus, 57, 322, 1984.

"Spectral Characteristics of Two Types of Low Latitude Aurorae" B. Tinsley, R. Rohrbaugh, H. Rassoul, E. Barker, A. Cochran, W. Cochran, B. Wills, D. Wills, and D. Slater, Geophys. Res. Letters, 11, 572, 1984.

"Abundance of Interstellar Aluminum" E. Barker, P. Lugger, E. Weiler, and D. York, Ap. J., 280, 600, 1984.

B. Submitted Papers

"Long Term Changes in Saturn's Troposphere" L. Trafton, Icarus.

"Seasonal Variations in Triton's Atmospheric Mass and Composition" L. Trafton, Proceedings of the Voyager Uranus/Neptune Workshop.

"Minor Planet 1983TB: A Dead Comet?" A. Cochran and E. Barker, Icarus.

"C₂ Photolytic Processes in Cometary Comae" A. Cochran, Ap. J..

"The Use of Self-Scanned Silicon Photodiode Arrays for Astronomical Spectrophotometry" A. Cochran, Proceedings of NASA Workshop on High Precision Techniques in Astronomy.

"High Precision Measurement of Stellar Radial Velocity Variations"
W. Cochran Proceedings of NASA Workshop on High Precision Techniques in
Astronomy.

"Absolute Spectrophotometry of Uranus, Neptune, and Titan:
3500-10500 Å " J. Neff, D. Humm, J. Bergstralh, A. Cochran, W. Cochran,
E. Barker, and R. Tull, Icarus.

C. Presentations and Abstracts

1) At the 164th meeting of the American Astronomical Society,
Baltimore, Md:

"In Orbit Test and Calibration of the High Resolution Spectrograph
for the Hubble Space Telescope" S. P. Maran, J. C. Brandt, B. D. Savage,
D. Ebbets, E. A. Beaver, A. Boggess, S. R. Heap, J. B. Hutchings, M. A. Jura,
D. S. Lektone, J. L. Linsky, A. M. Smith, L. M. Trafton, and R. J. Weymann,
B.A.A.S., 16, 477, 1984.

2) At the Voyager Uranus/Neptune Workshop, Pasadena, CA,
February 6-8, 1984:

"Seasonal Variations in Triton's Atmospheric Mass and Composition"
L. Trafton.

3) At the NASA Workshop on High Precision Techniques in Astronomy,
San Diego, CA, June 18-19, 1984.

"The Use of Self-Scanned Silicon Photodiode Arrays for Astronomical
Spectrophotometry" A. Cochran (invited talk).

"High Precision Measurement of Stellar Radial Velocity Variations"
W. Cochran (invited talk).